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EMISSIONS OF OXIDES OF NITROGEN FROM STATIONARY SOURCES IN LOS ANGELES COUNTY

Robert L. Chass

Los Angeles County Air Pollution Control District
Los Angeles, California

1959

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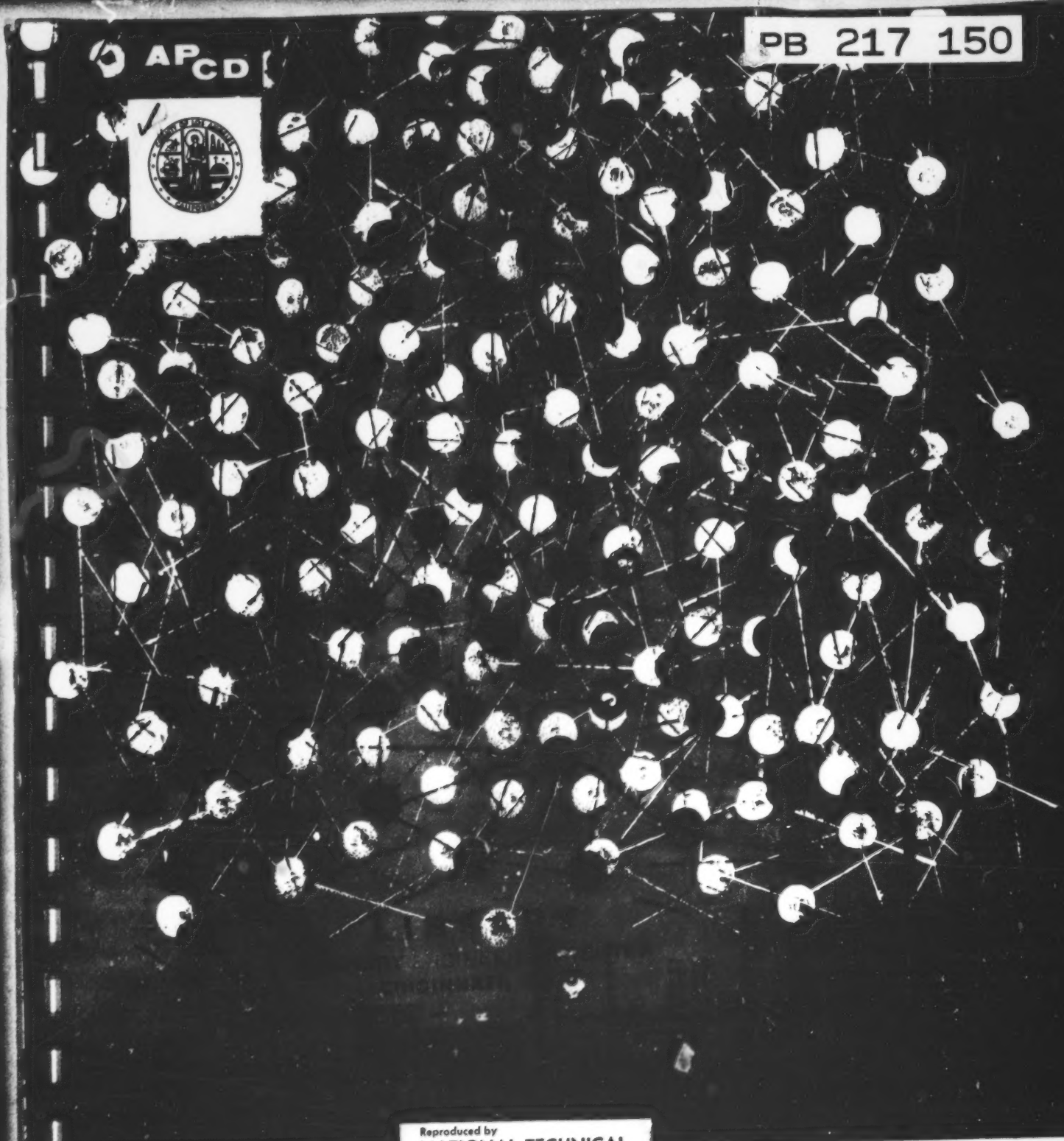

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A joint project

EMISSIONS OF OXIDES OF NITROGEN FROM STATIONARY SOURCES IN LOS ANGELES COUNTY / *Report No. 1*

AIR POLLUTION CONTROL DISTRICT/COUNTY OF LOS ANGELES

56

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Details of illustrations in this document may be better studied on microfiche.

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FOREWORD

Almost ten years ago it was found that oxides of nitrogen, by reacting in the atmosphere with certain organic compounds, play an important role in the formation of the eye-irritating smog of Los Angeles County. Significant quantities of oxides of nitrogen are emitted into the atmosphere from all types of operations in which oxygen and nitrogen are subjected to temperatures sufficiently high to cause fixation.

Many measurements have been made, both of the concentration of oxides of nitrogen in the atmosphere and of the contribution of oxides of nitrogen from various types of man-made sources. These measurements indicate that, by far, the most important sources of oxide of nitrogen emissions in Los Angeles County are gasoline-powered automotive vehicles which contribute approximately 60 per cent of the total. The study of the automobile as a source of oxides of nitrogen and hydrocarbons has been carried on intensively for some time by many agencies. The study of emissions of oxides of nitrogen from stationary sources, however, has proceeded largely as a series of auxiliary tests in which the discharges of other types of air contaminants were the primary objects of investigation.

A survey of the data available on the emissions of oxides of nitrogen from stationary sources showed that a great deal of additional test data was needed in order to obtain accurate knowledge of the quantities of oxides of nitrogen emitted to the atmosphere from these non-automotive units of equipment.

This need and the recognized importance of the role of oxides of nitrogen in smog formation led to the establishment of the Joint Project for the Determination of Emissions of Oxides of Nitrogen from Stationary Sources in Los Angeles County. Agencies represented in this project are the Los Angeles County Air Pollution Control District, the United States Public Health Service, the California State Department of Public Health, public and private utilities, and the petroleum industry.

This is the first of a series of reports which will be published on the work and findings of this Joint Project.

ROBERT L. CHASS

Director of Engineering
Air Pollution Control District

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I. INITIATION OF THE PROJECT

Based on preliminary studies concluded in April of 1959, Los Angeles County Air Pollution Control District personnel estimated that approximately 300 tons per day of oxides of nitrogen are emitted into the atmosphere from stationary sources in Los Angeles County.[1,2] The investigators pointed out, however, that the available data were neither sufficiently complete nor reliable enough to use either in making an accurate estimate of the total quantity of this type of air pollution or in determining the operating conditions under which these oxides are produced. Considering the fact that the District must be cognizant of the quantitative aspects of air contamination of every type, it was obvious that it would be necessary to collect reliable data regarding the emissions of oxides of nitrogen from all categories of industrial, commercial and residential sources.

As a result of these findings, the Air Pollution Control Officer directed that a project be initiated with this objective: to obtain accurate data concerning the total amount of air pollution by oxides of nitrogen emitted from the various stationary sources in Los Angeles County. The importance and magnitude of the project were deemed such that the Air Pollution Control District invited the participation of the United States Public Health Service, the California State Department of Public Health, the Los Angeles City Department of Water and Power, the Public Service Departments of the Cities of Burbank and Glendale, the Light and Power Department of the City of Pasadena, the Southern California Edison Company, the Southern California Gas Company, the Southern Counties Gas Company, and the Western Oil and Gas Association. Each of these organizations accepted the invitation and designated a representative to serve on the committee for the project. The Joint Project for the Determination of Emissions of Oxides of Nitrogen from Stationary Sources in Los Angeles County began on July 10, 1959, when the first meeting of the Committee was held.

SUBCOMMITTEES

To insure that all aspects of the program would be adequately planned and reviewed, it was deemed necessary to create three subcommittees. The membership of these subcommittees is as follows:

Subcommittee on Scope

H. Carter Austin, Southern California Edison Company - Chairman
Russell T. Mapston, Western Oil and Gas Association
Guy Corfield, Southern California Gas Company and Southern Counties Gas Company
John L. Mills, Los Angeles County Air Pollution Control District

Subcommittee on Methods

Carl V. Kanter, Los Angeles County Air Pollution Control District - Chairman
Hans H. Sonderling, City of Los Angeles Department of Water and Power
Chadwell O'Connor, City of Pasadena Department of Light and Power

Editorial Subcommittee

John L. Mills, Los Angeles County Air Pollution Control District - Chairman
H. Carter Austin, Southern California Edison Company
Hans H. Sonderling, City of Los Angeles Department of Water and Power
Russell T. Mapston, Western Oil and Gas Association

The Subcommittee on Scope was assigned the task of determining the categories of sources of oxides of nitrogen to be tested and the conditions under which tests are to be made. In addition, this subcommittee formulated the following as the purpose of the project:

> To test for oxides of nitrogen an adequate number of representative devices in each category of stationary sources in Los Angeles County under sufficient varying operating conditions to insure the determination of the total emissions to the atmosphere and emission factors for oxides of nitrogen from each of the major classifications of stationary equipment.

The Subcommittee on Methods was requested to study the various methods available for measuring oxides of nitrogen and to recommend procedures to be followed for the test program. The sampling and analytical procedures selected and developed by this subcommittee appear in Section IV of this report.

The Editorial Subcommittee has the responsibility of preparing all reports of the work and findings of the project. It is anticipated that the following additional reports will be issued:

TITLE	TARGET DATE
Oxides of Nitrogen Emissions From Small Sources	April 30, 1960
Oxides of Nitrogen Emissions From Medium Sources	July 31, 1960
Oxides of Nitrogen Emissions From Large Sources	October 31, 1960
Final Report	December 31, 1960

MANPOWER ASSIGNMENTS

The preliminary report prepared by Mills et al.[2] included a tabulation of proposed additional equipment to be tested. This tabulation included a list of the types of sources for which either no information or sparse information was available. From this tabulation it was estimated that approximately 100 additional tests would be needed and that these tests would require approximately 5,000 man-hours of work.

The United States Public Health Service furnished two engineers to the project. The California State Department of Public Health furnished one engineer. The Air Pollution Control District assigned the full-time services of four engineers in addition to the project director, the assistant project director, and the project leader.

II. OXIDES OF NITROGEN AND THE AIR POLLUTION PROBLEM

Although oxides of nitrogen have been known for two hundred years or more, their role in air pollution has been realized only in the last decade. The known oxides of nitrogen are presented in Table I[3].

TABLE I

THE OXIDES OF NITROGEN

Formula	Name	State at Room Temperature	Color
N_2O	Nitrous oxide	Gas	Colorless
NO	Nitric oxide	Gas	Colorless
N_2O_3	Nitrogen sesquioxide	Gas	Red-brown
NO_2	Nitrogen dioxide	Gas	Red-brown
N_2O_4	Nitrogen tetroxide	Gas-Liq.	Colorless
N_2O_5	Nitrogen pentoxide	Solid	Colorless
NO_3	Nitrogen trioxide	--	--

Nitrous oxide occurs naturally in the atmosphere in concentrations approaching 1 ppm[4]. This oxide does not appear to enter into the smog reactions. Nitrogen sesquioxide is very unstable at room temperature and above, decomposing rapidly into nitric oxide and nitrogen dioxide[3]. Nitrogen trioxide is extremely unstable, decomposing at temperatures above -142°F , and does not exist under atmospheric conditions. Nitrogen pentoxide is the anhydride of nitric acid. It occurs in polluted atmospheres only in extremely minute concentrations, if at all, and therefore is not an important oxide of nitrogen from the standpoint of air pollution reactions.

The two important oxides of nitrogen from the standpoint of air pollution are nitric oxide (NO) and nitrogen dioxide (NO_2)[5]. NO_2 is always present in equilibrium with nitrogen tetroxide, N_2O_4; but in the conditions existing in the atmosphere, NO_2 predominates. The presence of these oxides of nitrogen in the Los Angeles atmosphere in the concentrations found cannot be explained by natural processes. These oxides have been found in the discharge gases from many types of man-made sources such as automobiles, industrial and domestic combustion equipment, electric arc processes, or chemical reactions.

NITROGEN OXIDES AT THE SOURCE

Any mixture of nitrogen and oxygen (air) subjected to high temperatures (2800 - 4000°F), as are provided by a flame or an electric arc, will produce a measurable quantity of nitric oxide, NO, according to the reaction:

$$N_2 + O_2 + 43,200 \text{ calories} = 2\,NO$$

NO decomposes to nitrogen and oxygen when it is cooled slowly from formation temperatures to 2800°F. The cooling rate in most equipment is faster than the decomposition rate so that significant concentrations of nitric oxide are found in the flue gases. Ermenc[6] suggests that the very high cooling rate of 30,000°F per second from formation temperature to a temperature below 2800°F is required to prevent any decomposition. Below 2800°F, no apparent decomposition occurs.

THE AIR POLLUTION PROBLEM

Nitric oxide oxidizes at room temperature in air to nitrogen dioxide. At an original concentration of 1000 ppm of NO, one-half will be converted to NO_2 in about 5 minutes. After NO is diluted to the concentrations found in the atmosphere, the rate of oxidation drops rapidly. At 1 ppm of NO, it takes about 100 hours for half the NO to be converted to NO_2. At 0.1 ppm of NO, it will take about 1000 hours for 50 per cent oxidation to NO_2. With ozone present, however, the oxidation rate is greatly increased. At 0.1 ppm each of ozone and NO, 50 per cent conversion takes less than one minute.[7] Possibly the presence of certain hydrocarbons may also cause a rapid conversion of NO to NO_2[8].

Although NO_2 is a toxic gas, the concentrations found in the atmosphere, even during heavy smog periods, have not been demonstrated to be hazardous to health. Thus, interest in the oxides of nitrogen as air pollution agents arises primarily because of their role in atmospheric reactions to produce other compounds which contribute toward the undesirable smog manifestations. The remote potential of oxides of nitrogen in the atmosphere as a health hazard is not a consideration in the studies of the Joint Project.

Research has shown that in the atmosphere oxides of nitrogen react with certain hydrocarbons to form other contaminants which give rise to the various manifestations of Los Angeles-type smog, such as eye irritation, reduced visibility, damage to vegetation, and rubber cracking[9]. Many papers have been published describing the

mechanism of the reactions in the atmosphere involving oxides of nitrogen[9, 10, 11]. A discussion of the mechanism of these reactions is beyond the scope of this report; it is sufficient to state here that atmospheric reactions involving oxides of nitrogen and hydrocarbons produce other atmospheric contaminants such as ozone, organic peroxides, organic compounds containing nitrogen and other oxidation products of hydrocarbons. A very complex array of products is the result, and among these products are the agents responsible for the various undesirable smog effects.

III. THE PROGRAM

Data and information on the discharge of oxides of nitrogen have been collected over a period of years by the Air Pollution Control District during tests of specific units of equipment. The amounts of oxides of nitrogen emitted are extremely variable. One of the objectives of this Project is to determine the rate of discharge of oxides of nitrogen from each type of equipment under varying operating conditions.

In the preparation of their report, Mills et al.[2] tabulated the results of over 200 tests made by the Air Pollution Control District and concluded that the equipment tested could be classified arbitrarily but logically into three groups, based on the discharge of total oxides of nitrogen in pounds per hour per unit of equipment. These groups were defined as follows:

Large Sources	-	those emitting over 100 pounds per hour per unit
Medium Sources	-	those emitting 5 to 100 pounds per hour per unit
Small Sources	-	those emitting less than 5 pounds per hour per unit

Figure 1 shows the distribution of test data from which the group divisions described above were selected. It can be seen that the greatest number of tests have been made on the small sources.

There are approximately 75 large sources in Los Angeles County. The exact number of medium sources is not known but is estimated to be in excess of 500 units. The number of small sources is judged to be in the hundreds of thousands. By taking the average daily emission for each type of unit and multiplying by the known or estimated number of such units in existence, the daily production of oxides of nitrogen can be estimated for each type of equipment. The following summarizes the results of such calculations made from the data studied prior to the initiation of the Project:

Large Sources	-	203 tons per day
Medium Sources	-	62 tons per day
Small Sources	-	29 tons per day
Total		294 tons per day

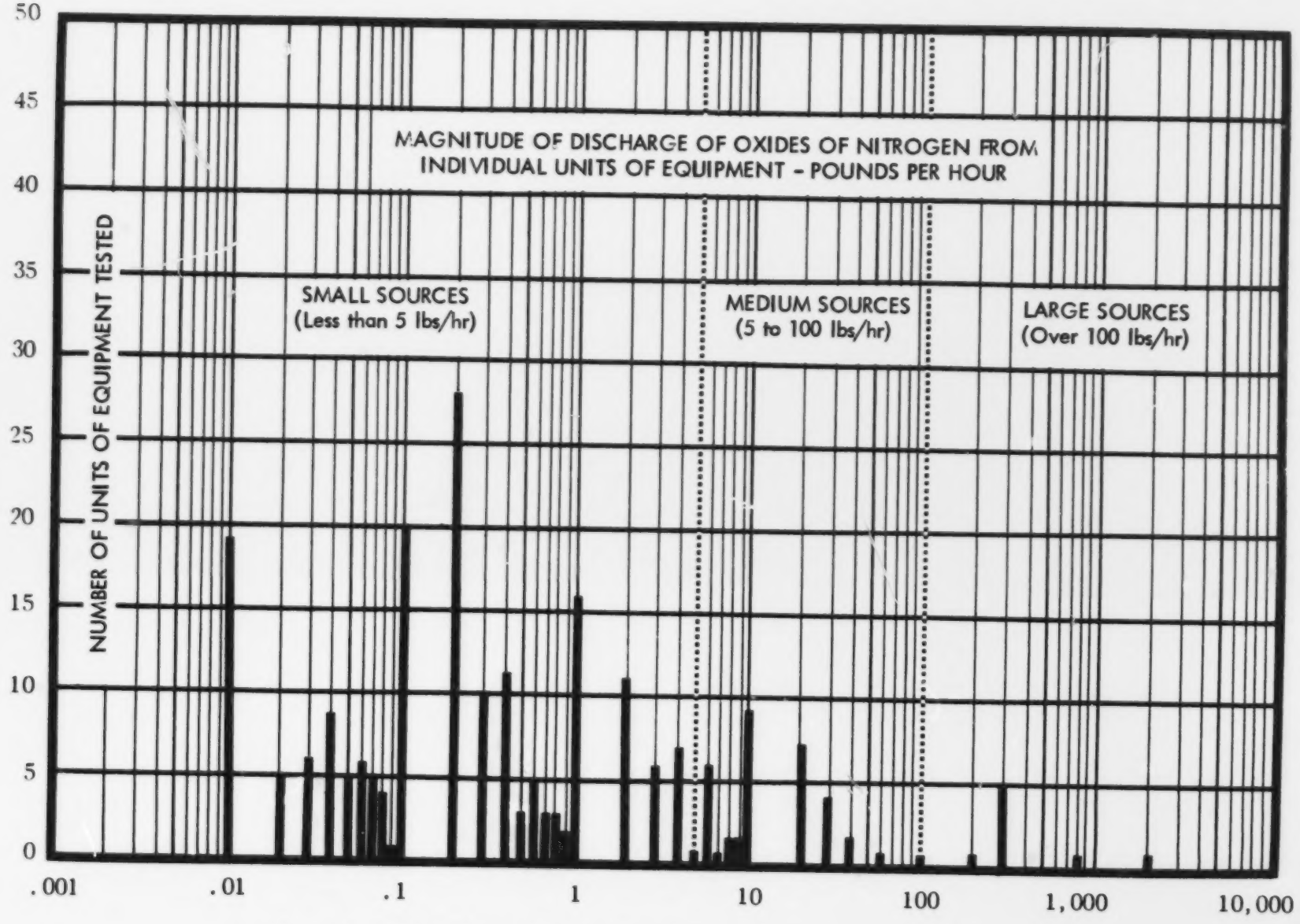

Figure 1. Distribution of oxides of nitrogen data from tests made by the Los Angeles County Air Pollution Control District

TABLE II

TENTATIVE TEST PROGRAM FOR OXIDES OF NITROGEN

Equipment by Source Category	Number of Units in L.A. County	Unit Census Required	Tests Completed by APCD	Additional Tests Proposed
A. LARGE SOURCES				
1. Power plant boilers	62	No	7	36
2. Catalytic regenerators in oil refineries	15	No	14	3
B. MEDIUM SOURCES				
1. Large refinery boilers and heaters	(est) 100	Yes	6	3
2. Other large boilers (200 h.p. and over)	(est) 200	Yes	15	10
3. Electric arc steel furnaces (over 1/2-ton capacity)	25	No	0	4
4. Asphalt paving plants	48	No	1	3
5. Large reverberatory metal melting furnaces (non-ferrous)	21	No	0	6
6. Glass melting furnaces	15	No	2	2
7. Miscellaneous				
a. Phosphate kilns	2	No	0	1
b. Boric oxide furnaces	2	No	0	1
c. Detergent spray driers	10	No	0	1
d. Rock wool cupolas	6	No	0	1
e. Perlite furnaces	10	No	0	1
f. Municipal incinerators	14	No	18	0
C. SMALL SOURCES				
1. Small boilers (under 200 h.p.)	Not known	Yes	6	5
2. Domestic equipment				
a. Hot water heaters	Not known	Yes	1	5
b. Refrigerators	Not known	Yes	1	5
c. Space heaters	Not known	Yes	1	5
d. Stoves	Not known	Yes	0	5
e. Clothes driers	Not known	Yes	1	5
3. Small refinery heaters and boilers	(est) 230	Yes	6	3
4. Small incinerators (less than 1000 lbs./hr.)	(est) 1000	Yes	96	0
5. Drying and baking ovens	(est) 2500	Yes	23	10
6. Ceramic kilns	65	No	5	3
7. Gray iron cupolas	44	No	2	1
8. Open hearth steel furnaces	4	No	0	1
9. Induction metal melting furnaces	35	No	1	1
10. Crucible metal melting furnaces	937	No	1	3
11. Afterburners	(est) 500	Yes	13	10
12. Stationary internal combustion engines	464	No	0	10
13. Miscellaneous				
a. Rubber curing ovens	(est) 100	Yes	0	1
b. Rock wool driers	10	No	0	1
c. Bright dip tanks	2	No	0	1
d. Steel chemical milling tanks	4	No	0	1
e. Arc welding machines	(est) 3000	Yes	0	1
f. Nitric acid plants	1	No	0	1
g. Sulfuric acid plants	5	No	1	1
TOTALS			221	151

The program of the Project will include obtaining sufficient data to provide reliable totals for each category. Table II outlines the tentative future test program. When a sufficient number of tests has been completed in each group, the program will be reviewed to provide for any additional testing or any curtailment of testing that may be judged needful or desirable. The test program will be augmented continuously by the taking of oxides of nitrogen samples during routine tests of equipment being made by the District for other purposes.

IMPLEMENTATION OF THE PROJECT

The program developed to implement the overall objective may be summarized as follows:

1. To select, adopt or develop sampling and analytical methods.

2. To investigate all types of stationary equipment capable of emitting oxides of nitrogen.

3. To test a sufficient number of units of all such types of equipment under varying operating conditions in order that reliable emission factors may be determined.

4. To develop an accurate census for each type of stationary source of oxides of nitrogen.

5. To evaluate, classify and extrapolate test results to produce a reliable estimate of the total amount of oxides of nitrogen in tons per day emitted from stationary sources in Los Angeles County.

DEFINITIONS

The following definitions of terms will govern the carrying out of the Project:

1. Stationary Sources. A stationary source is considered to be any unit of equipment capable of emitting oxides of nitrogen and which must remain in one place to accomplish its function. Portable equipment which cannot be operated while being moved is considered to be stationary for the purposes of this Project. Internal combustion engines operating stationary equipment are included among stationary sources.

2. Source Categories. For the purpose of this Project, stationary sources will be grouped into three categories, according to the capabilities of an individual unit for emitting oxides of nitrogen:

   a. Large Sources - those emitting over 100 pounds per hour
   b. Medium Sources - those emitting 5 to 100 pounds per hour
   c. Small Sources - those emitting less than 5 pounds per hour

3. Emission Factors. An emission factor is a figure representing the discharge of oxides of nitrogen in weight per unit time from a typical unit of equipment operating under designated conditions. Such a factor multiplied by the number of units of a given type and the appropriate usage factor will yield the total rate at which airborne oxides of nitrogen will be produced by all units of that type.

4. Usage Factor. A usage factor is a figure representing the proportionate time a given type of equipment is operated under designated conditions.

5. Census. A census of units of equipment of a given type consists of an actual count when the number is small or a reliable estimate when the number is large.

IV. SAMPLING AND ANALYTICAL PROCEDURES

The Subcommittee on Methods reviewed the various analytical procedures available for the determination of oxides of nitrogen, including the phenoldisulfonic acid method, the Griess-Saltzman method, and infrared spectrophotometry. The Subcommittee unanimously selected the phenoldisulfonic acid method because of its reliability, reproducibility, and its suitability for field testing.

The phenoldisulfonic acid method has been accepted for many years by most laboratories as the best technique for determining low concentrations of nitrates in water. Modifications have been made for the determination of oxides of nitrogen in gaseous emissions, and the technique has proved to be reliable and reproducible.

Analytical laboratories representing several of the agencies in the project collaborated in a program to check the sampling and analytical details involving the phenoldisulfonic acid procedure to adapt them for the specific uses of the oxides of nitrogen project.

As the project progresses, changes or improvements in the sampling and analytical techniques which may be indicated will be recommended by the Subcommittee for incorporation into the official procedure. Any changes made will be published in future reports.

The sampling and analytical procedures adopted by the Joint Project are as follows:

MEASUREMENTS TO BE MADE

This procedure is used to determine oxides of nitrogen (expressed as nitrogen dioxide) from stationary sources where the concentration range is five to several thousand parts per million.

Sampling the exhaust gases at a particular source is carried out during various load conditions. It is preferable to sample during periods when steady-state operation is maintained. During the sampling period, at equal time intervals, the following samples and data are taken:

Grab samples for determining oxides of nitrogen

Orsat samples to determine carbon dioxide, carbon monoxide, oxygen, and nitrogen

Velocity head reading

Stack gas temperature

Wet bulb and dry bulb temperatures.

Equipment operational data are recorded on forms as shown in the appendix.

DETERMINATION OF GAS VELOCITY AND FLOW RATE

A standard or special Pitot tube is usually used in the measurement of gas velocity. The cross-sectional area of the stack is divided into a number of equal areas, and Pitot readings are made at the center of each area. For circular stacks the equal areas are concentric rings, and the traverse points are taken on the circles dividing the rings into two equal areas. Table III shows the distances to the traverse points as percentages of the stack diameter:

TABLE III

DISTANCE TO CENTERS OF EQUAL AREA ZONES FOR VELOCITY TRAVERSE, PER CENT OF STACK DIAMETER FROM CIRCUMFERENCE TO TEST POINT

Point Number	Number of Areas Chosen				
	2	3	4	5	6
1	6.2	4.4	3.3	2.2	2.0
2	25.0	14.7	10.5	8.2	6.7
3	75.0	29.4	19.5	14.5	11.8
4	93.8	70.6	32.1	22.7	17.7
5		85.3	67.9	34.4	25.0
6		95.6	80.5	65.6	35.4
7			89.5	77.3	64.6
8			96.7	85.5	75.0
9				91.8	82.3
10				97.8	88.2
11					93.3
12					98.0

The gas velocity for each of the points measured with the Pitot tube is calculated from the relation:

$$V = 2.90\,FG\,\sqrt{\frac{29.92}{P} \times HT}$$

Where

V = velocity, feet per second

F = Pitot tube factor (F = 1.0 for the standard Pitot tube)

P = stack gas pressure, inches of mercuty absolute

G = gas specific gravity correction factor (for air G = 1). (See page 31)

H = draft gauge reading, inches of water

T = stack gas temperature, degrees Rankine ($^{o}F + 460$)

The temperature of the stack gas must be determined at the time the Pitot readings are taken. A thermocouple is usually used for this purpose. If the temperature is not uniform throughout the cross-sectional area in which the Pitot readings are made, the temperature must be taken at the same location as the Pitot reading.

The calculated velocities are averaged and multiplied by the cross-sectional area of the stack to give gas flow rate. If the flow rate is not constant over the period of time during which the samples for oxides of nitrogen determination are taken, a convenient point in the stack should be selected for use as a reference point, and readings should be taken at this point when the velocity traverses are made. A flue factor, which is the ratio of average stack velocity to reference point velocity, is determined. The average velocity in the stack at any time can then be determined by multiplying the reference point velocity by the flue factor.

If the velocity is less than five feet per second, some other method of measurement such as the use of an anemometer may be necessary.

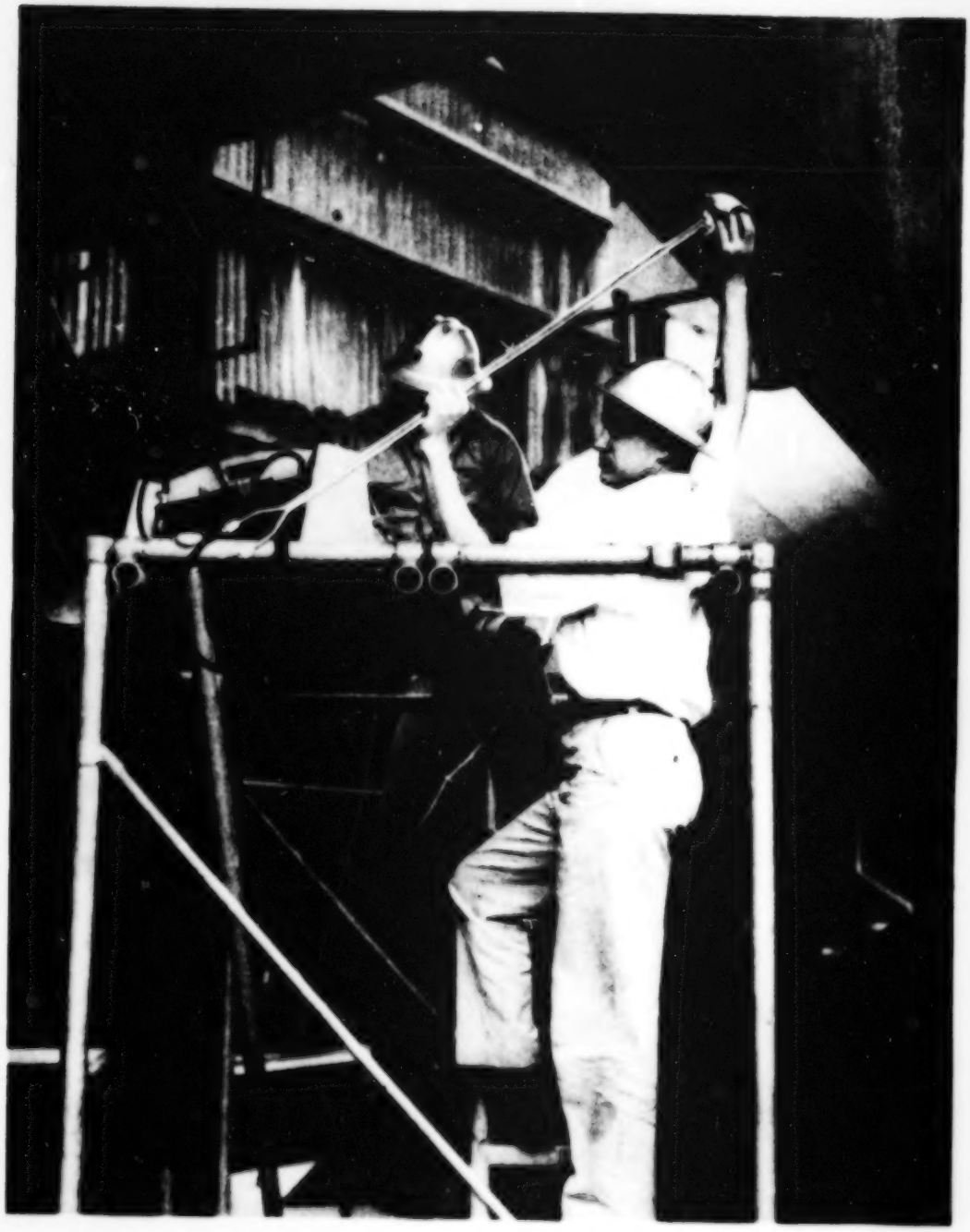

Figure 2. Pitot tube being used to measure gas velocity in a circular duct.

MOISTURE DETERMINATION OF FLUE GAS

BY WET AND DRY BULB TEMPERATURES

If the temperature in the flue is below 212°F, wet and dry bulb readings may be taken directly in the flue. Where the temperature in the flue is above 212°F, wet and dry bulb readings for use with conventional psychrometric charts may be taken if the gases are first cooled. This can be done by inserting into the flue a length of 3/4-inch standard pipe fitted with two standard "tees" and a connection to a steam or air aspirator or a pump. A dry bulb thermometer is inserted into the opening of the first tee and a wet bulb thermometer similarly into the second tee by means of rubber stoppers. Proper temperatures can be obtained by adjusting the length of pipe ahead of the tees and by regulating the rate of flow. The gases must be kept at a temperature high enough to prevent condensation. The tees should be coupled as closely as possible.

ALTERNATE METHOD

In place of the above, which will be used preferably, the following impinger method may be substituted.

The amount of moisture in the stack gas may be determined by drawing a sample though three impingers in series in an ice bath followed by a dry gas meter and a vacuum pump. The first two impingers each contain 100 ml of distilled water and the third impinger is dry with a thermometer attached to the stem. The recommended flo' rate is 0.5 to 1.0 cubic feet per minute with a sampling time of at least one hour. The following readings are taken at regular time intervals during the sampling:

Meter reading (also taken at start and end of run)

Meter vacuum

Gas temperature at meter

Temperature in third impinger

At the end of the run, the volume of water in the impingers is measured in a 250-ml graduate to determine the amount condensed out from the stack gases. The volume of water vapor condensed in the impingers is:

$$W = \frac{C}{453.6} \times \frac{379}{18} \times \frac{Tm}{520} \times \frac{29.92}{P_a - P_m} = 0.00267\, C \frac{T_m}{P_a - P_m}$$

Where

W = vapor volume of condensed moisture at meter conditions, ft^3

C = volume of condensed water, milliliters

T_m = temperature in meter, degrees Rankine ($^oF + 460$)

P_a = atmospheric pressure, inches of mercury

P_m = meter vacuum, inches of mercury

The volume of water vapor in the metered sample is calculated on the assumption that the sampled volume measured by the meter is saturated with water vapor at the temperature in the third impinger.

$$W_v = \left(\frac{V.P.}{P_a - P_m} \right) \times V_m$$

Where

W_v = water vapor volume in metered sample, ft^3

V.P. = vapor pressure of water at impinger temperature, inches of mercury

P_a = atmospheric pressure, inches of mercury

P_m = meter vacuum, inches of mercury

V_m = metered volume of sample

Volume per cent of moisture in the stack gases $= 100 \left(\frac{W + W_v}{W + V_m} \right)$

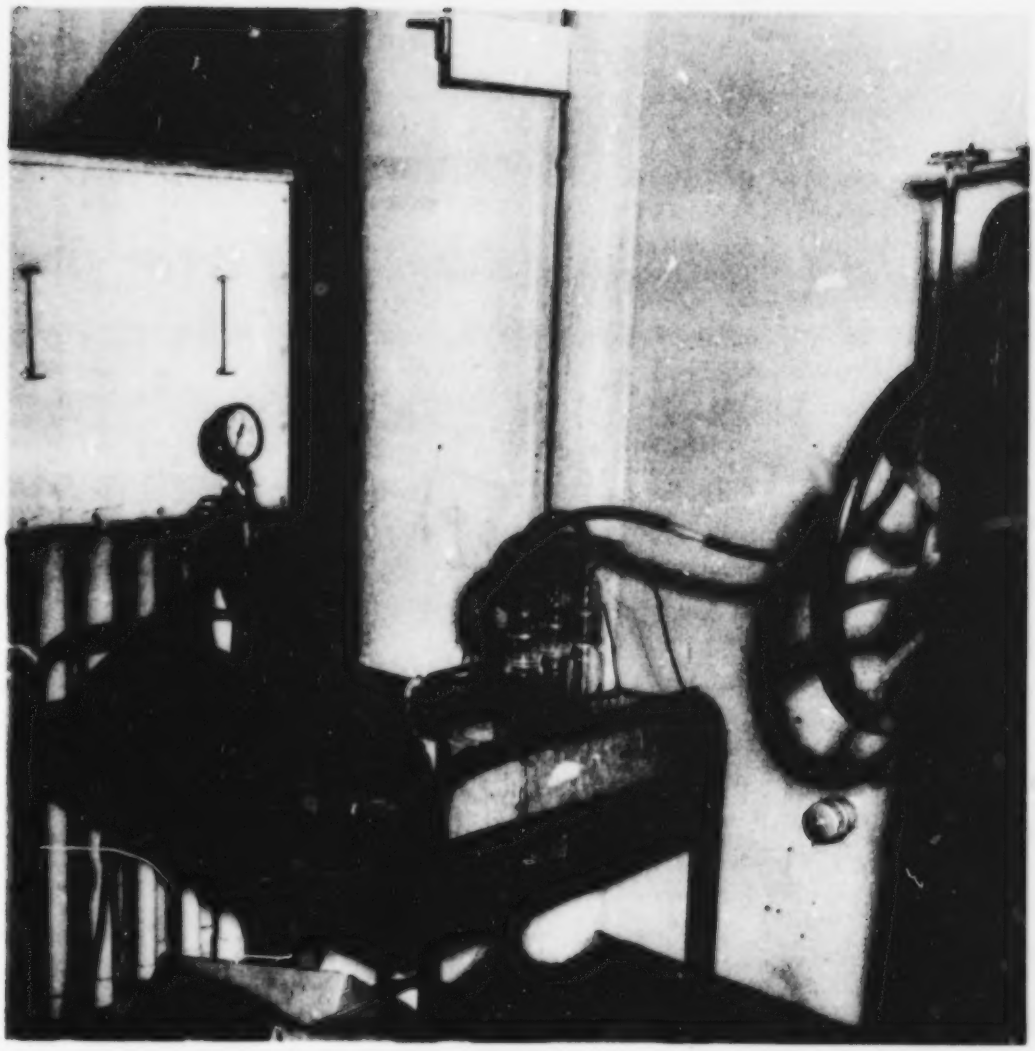

Figure 3. Equipment needed for alternate method of determining moisture in flue gases (impinger method).

DETERMINATION OF CARBON DIOXIDE, CARBON MONOXIDE, OXYGEN, AND NITROGEN BY ORSAT METHOD

METHOD SUMMARY

The sample is collected by liquid displacement of a saturated, acidified sodium sulfate solution. 100 ml of sample are transferred into the burette of the Orsat analyzer and then passed through a potassium hydroxide solution to remove carbon dioxide. The sample is passed back into the burette and the amount of carbon dioxide absorbed is read. Oxygen in the gas sample is determined by absorption in alkaline pyrogallol and the carbon monoxide by absorption in a cuprous chloride solution. Small amounts of carbon monoxide are determined colorimetrically in a special apparatus such as the MSA carbon monoxide tester.

APPARATUS

5-liter stoppered bottle with a 2-inch neck and with a glass tube extending just below the stopper for collection or removal of the sample and two glass tubes extending almost to the bottom of the bottle--one with a rubber or tygon tubing connection and a screw clamp for the removal of displaced liquid and one with a funnel and stopcock above the bottle to use to maintain a pressure slightly above atmospheric after the sample is collected.

1-gallon bottle to collect the displaced fluid

Stainless steel sample nozzle, 3/16-inch i.d.

Burrell Portable Orsat Analyzer

MSA Carbon Monoxide Tester

REAGENTS

Saturated, acidified sodium sulfate solution for sample collection.

To make five gallons of solution, dissolve 3600 grams of sodium sulfate decahydrate in 17,500 ml of water. Add

486 ml of concentrated sulfuric acid and 9 ml of methyl orange.

Caustic solution for CO_2 determination.

Add 140 ml water to 60 gm KOH. Dissolve the KOH completely and allow the solution to cool in a rubber-stoppered bottle.

Solutions for O_2 determination.

Solution A. Add 97 ml water (boiled) to 48.5 gm NaOH. Dissolve the NaOH completely, allow the solution to cool and store in a stoppered container.

Solution B. Add 41.5 ml H_2O (boiled) to 14 gm of pryogallic acid. Dissolve the acid completely and store the solution in a tightly-stoppered container.

Final solution. Mix solutions A and B when ready to use and add quickly to the pipette. Do not allow the solution to remain in contact with the air.

Acid cuprous chloride solution for CO determination.

Add cuprous chloride crystals to 1 liter of 6N HCl and mix until saturation is indicated by the presence of undissolved crystals remaining in the bottom of the container. Then add a few small pieces of clean metallic copper. Shake the bottle at intervals over a period of a few days until the solution becomes colorless.

COLLECTION OF THE SAMPLE

Before collecting the sample, the displacement liquid is saturated with the gas to be collected. An integrated stack sample for Orsat analysis is then collected by withdrawing gases continuously at a constant rate through a stainless steel tube. The 5-liter bottle filled with the saturated, acidified sodium sulfate solution is used as the collecting gas holder. As the solution siphons out, the gas sample is drawn into the bottle. The rate of siphoning is adjusted so that a gas sample of about 4 liters is obtained during the course of the test. After the gas sample is collected, the solution in the funnel extending through the top of the bottle is allowed to flow

down to maintain a pressure in the bottle slightly above that of the atmosphere.

Samples from a combustion chamber are taken as close as possible to the point where combustion is complete so that the calculated per cent excess air does not include dilution air.

If samples are to be taken at frequent intervals, 250-ml or 500-ml MSA tubes filled with the sodium sulfate displacement fluid are used to collect the samples, rather than the 5-liter bottles. For spot checks, the gas is drawn directly from the source into the burette of the Orsat analyzer.

ANALYTICAL PROCEDURE

Transfer of sample to Burrell Portable Orsat Analyzer.

The leveling liquid in the Orsat apparatus should be saturated with the gases being tested. The manifold is swept free of gases from previous determinations by twice drawing approximately 100 ml of sample into the burette and then expelling it to the atmosphere. Slightly more than 100 ml of sample is then drawn into the burette. The burette stopcock is closed and the sample is allowed to stand for one minute to permit the acidified sodium sulfate solution confining liquid to drain down the sides of the burette. The leveling bottle is then elevated above the confining liquid in the burette until the liquid level in the burette is exactly 100, thus placing the gas under a pressure slightly above atmospheric. The connecting tubing to the leveling bulb is then closed off and the stopcock opened to the atmosphere momentarily, thus bringing the 100 ml of gas in the burette to atmospheric pressure.

Determination of Carbon Dioxide.

The burette leveling bulb is raised slightly, thus putting the gas in the burette under slight pressure to avoid any possibility of pulling solution from the pipette into the manifold. Then the manifold stopcock is turned to allow the gas to enter the pipette containing potassium hydroxide solution and the burette leveling bulb raised until the confining liquid approaches the top of the burette. The burette leveling bulb is lowered to bring the gas back into the burette. This process

Figure 4. Field analysis of flue gases using the Burrell Portable Orsat Analyzer.

is repeated three to four times, and the level of the potassium hydroxide solution is then brought to the reference point on the capillary stem of the pipette. The pipette stopcock is closed and the burette is read with the liquid in the leveling bulb and the burette at the same level.

The gas is passed twice more into the pipette as a check. If the reading is the same as before, all the carbon dioxide has been removed and the operator may proceed with the analysis. If more than six passes are required to get complete absorption, the solution is renewed.

Determination of Oxygen.

Following the previous procedure, the gas is passed into the pipette containing alkaline pyrogallol until constant readings are obtained. If more than 12 passes are required, the solution is replaced.

Determination of Carbon Monoxide.

The gas is passed into the cuprous chloride solution until constant readings are obtained. If the amount of CO appears to be 0.2 ml or less, an MSA CO Tester is used to measure the amount of CO.

REPORTING AND CALCULATIONS

The Orsat readings are on a dry basis. The per cent nitrogen is assumed equal to:

$$100 - (\%\,CO_2 + \%\,O_2 + \%\,CO)$$

To convert the percentages to a wet basis (stack conditions), the following calculation is employed:

$$\%\text{ wet basis} = \%\text{ dry basis} \times \left(1 - \frac{\%\,H_2O \text{ in stack gases}}{100}\right)$$

DETERMINATION OF OXIDES OF NITROGEN BY THE PHENOLDISULFONIC ACID METHOD

METHOD SUMMARY

The sample is collected in an evacuated flask containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (with the exception of nitrous oxide) to nitric acid. The resultant solution is made slightly alkaline and then evaporated to dryness and treated with phenoldisulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid which is formed is measured by a spectrophotometer.

DISCUSSION

A considerable excess of hydrogen peroxide is used in the absorbing solution and the sample is shaken and then allowed to stand overnight in contact with the oxidizing solution to obtain complete absorption of the oxides of nitrogen.

Nitrate-free reagents and a fume-free laboratory are necessary to maintain a consistently low blank. The magnitude of the blank increases with increasing concentrations of hydrogen peroxide as well as with the age of the phenoldisulfonic acid solution.

A glass wool filter plug should be placed in the sampling line to prevent particulate matter from entering the sampling flask. Iron compounds interfere with the analysis by developing a yellow color.

APPARATUS

Two-liter round bottom flask with a short length of 8-mm glass tubing connected to the neck, 3-inch length of heavy-wall gum-rubber tubing, screw clamp, and solid glass plug.

Coleman Model 14 Universal Spectrophotometer (other equipment can be adapted, e.g., Beckman Spectrophotometer, Klett-Summerson industrial colorimeter).

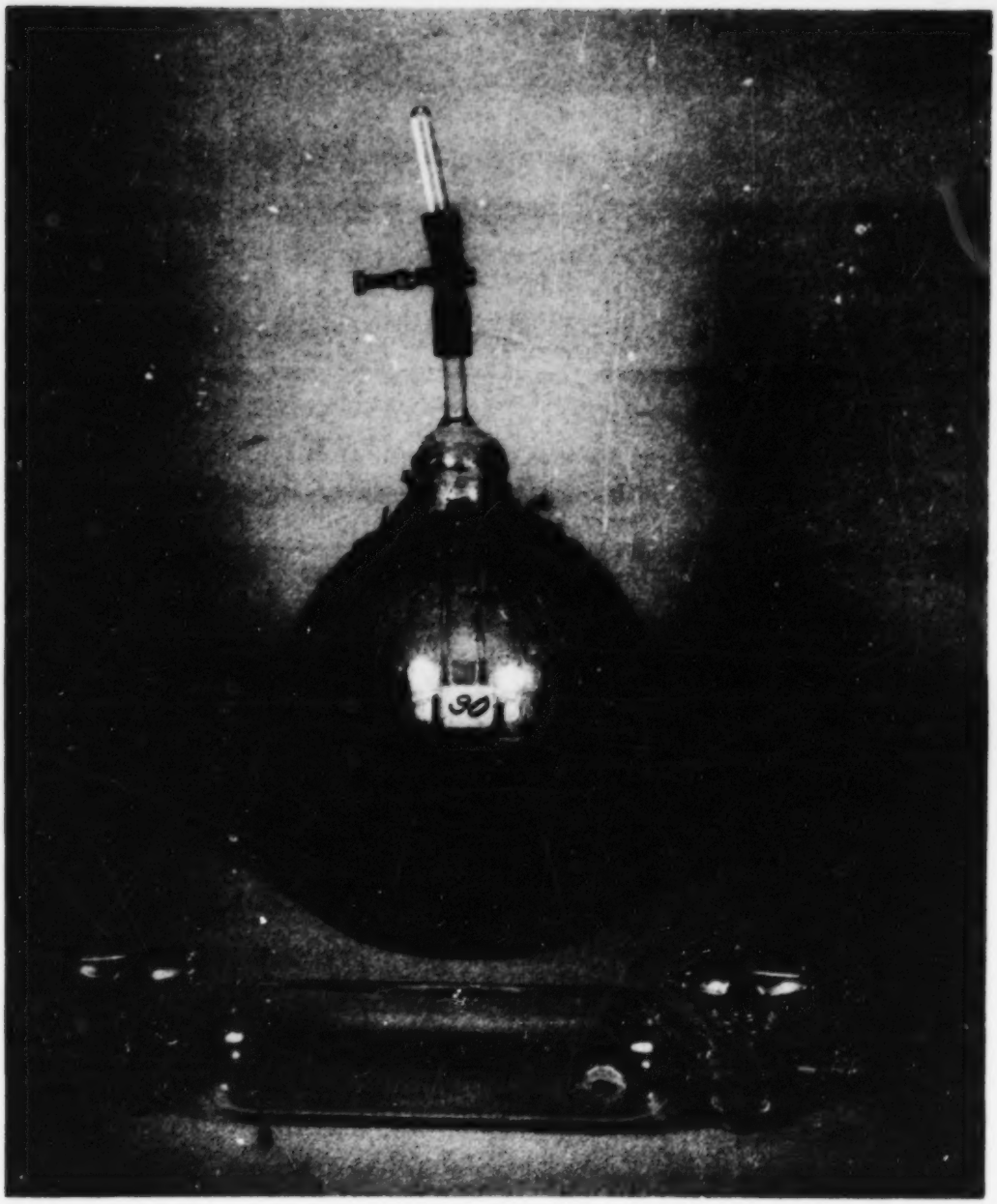

Figure 5. A. Two-liter flask for taking oxides of nitrogen sample.
B. 250-ml MSA sampling tube for taking intermittent sample for Orsat analysis.

REAGENTS

3% Hydrogen Peroxide.

Dilute 30% hydrogen peroxide (acetanilid free) 1:10 with water. This reagent should be prepared fresh daily.

0.1N (approximate) Sulfuric Acid.

Dilute 2.8 ml of concentrated sulfuric acid to one liter with water.

Absorbing Solution.

Add 1.5 ml of 3% hydrogen peroxide to each 100 ml of 0.1N (approximate) sulfuric acid needed for the particular day's work.

1N (approximate) Sodium Hydroxide.

Dissolve 40 grams of sodium hydroxide pellets in water and dilute to one liter.

Concentrated Ammonium Hydroxide.

Concentrated Sulfuric Acid.

Fuming Sulfuric Acid. (15 to 18% by weight of free sulfuric anhydride)

Phenoldisulfonic Acid Solution.

Dissolve 25 grams of pure white phenol in 150 ml of concentrated sulfuric acid on a steam bath. Cool and add 75 ml of fuming sulfuric acid. Heat to 100°C for two hours. Store in a brown glass-stoppered bottle. This solution should be colorless if prepared from reagent grade chemicals. (Phenoldisulfonic acid solution may also be prepared by mixing 40 ml of phenoldisulfonic acid with 222 ml of concentrated sulfuric acid.)

Standard Potassium Nitrate Solution A.

Accurately weigh 0.5495 gram of pure, dried potassium nitrate and dissolve in water. Make up to volume in a 1-liter volumetric flask with water. One milliliter of this standard solution contains the equivalent of 0.250 mg of nitrogen dioxide.

Standard Potassium Nitrate Solution B.

Dilute 100 ml of Standard Solution A to 1000 ml with water and mix well. One milliliter of this standard solution contains the equivalent of 0.025 mg of nitrogen dioxide.

PREPARATION OF CALIBRATION CURVES

Prepare four calibration curves, the first to cover a range of 0 - 100 ppm; the second, 50 - 500 ppm; the third, 500 - 1500 ppm; and the fourth, 1500 - 3000 ppm.

(1) 0 - 100 ppm. Using a microburette, transfer 0.0 (blank), 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 16.0, 20.0 ml of potassium nitrate Standard Solution B into separate 200-ml casseroles and add 25.0 ml of absorbing solution into each casserole. Follow as directed in the analytical procedure section starting with the addition of 1N sodium hydroxide. Read the absorbency of each solution, and subtract the blank reading.

(2) 50 - 500 ppm. Using a microburette, transfer 0.0 (blank), 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0 ml of potassium nitrate Standard Solution A into separate 200-ml casserole dishes and add 25.0 ml of absorbing solution to each casserole. Follow as directed in the analytical procedure section starting with the addition of 1N sodium hydroxide. After the yellow color is developed in each graduated centrifuge tube, make a 1:10 dilution by taking an aliquot of each of the standards and the blank. Read the absorbency of each solution, and subtract the blank reading.

(3) 500 - 1500 ppm. Using a 50-ml burette, transfer 0.0 (blank), 5.0, 10.0, 15.0, 20.0, 25.0, 30.0 ml of potassium nitrate Standard Solution A into separate 200-ml casseroles and add 25.0 ml of absorbing solution to each casserole. Follow as directed in the analytical procedure section starting with the addition of 1N sodium hydroxide. After the yellow color is developed in each graduated centrifuge tube, make a

1:20 dilution by taking an aliquot of each of the standards and the blank. Read the absorbency of each solution and subtract the blank reading.

(4) 1500 - 3000 ppm. Using a burette, transfer 0.0 (blank), 15.0, 30.0, 35.0, 40.0, 45.0, 50.0, 55.0, 60.0 ml of potassium nitrate Standard Solution A into separate 200-ml casseroles and add 25.0 ml of absorbing solution to each casserole. Follow as directed in the analytical procedure section starting with the addition of 1N sodium hydroxide. After the yellow color is developed in each graduated centrifuge tube, make a 1:50 dilution by taking an aliquot of each of the standards and the blank. Read the absorbency of each solution and subtract the blank reading.

Construct the curves for each of the four concentration ranges by plotting the net absorbencies of the solutions as ordinates against the milligrams of NO_2 as abscissas.

COLLECTION OF THE SAMPLE

Add 25 ml of freshly-prepared absorbing solution to the 2-liter collection flask. Evacuate the flask to the vapor pressure of the solution and tighten the clamp on the rubber-tubing sleeve. Stopper the open end of the rubber tubing with a small glass plug.

Using a pump or squeeze bulb, draw the flue gases through a sampling probe containing a fiberglass filter until the temperature of the gases at the end of the probe is above the dew point; then allow the gases to bleed into the sampling flask for about one minute. Close the screw clamp, insert the glass plug, and return the bulb to the laboratory for analysis.

ANALYTICAL PROCEDURE

Shake the flask for 15 minutes. Allow the flask to stand overnight to insure complete absorption of the oxides of nitrogen by the acid solution. When absorption is complete, the oxides of nitrogen (except nitrous oxide) will be converted to nitric acid.

Remove the glass plug, connect the rubber sleeve on the flask to an open-end mercury manometer, and open the screw clamp. Measure, in millimeters, the difference between the mercury levels. This reading is the difference between the pressure in the flask and atmospheric pressure. Record the room temperature and atmospheric pressure.

Figure 6. Use of two-liter evacuated flask in taking a sample of flue gas for oxides of nitrogen determination.

Transfer the contents of the 2-liter flask to a 200-ml casserole. Wash the flask three times with 15-ml portions of water and add the combined washings to the solution in the casserole. Add 25 ml of absorbing solution into another casserole for a blank and add the same amount of water to the dish (45 ml) that was used for transferring the sample. Proceed with the blank in the same manner as directed for the sample.

Add 1N sodium hydroxide to the solution in the casserole until it is just alkaline to litmus paper. Evaporate the solution to dryness on a water bath and then allow to cool. Carefully add 2 ml of phenoldisulfonic acid solution to the dried residue and triturate thoroughly with a glass rod, making sure that all of the residue comes into contact with the solution. Add 1 ml of water and 4 drops of concentrated sulfuric acid and heat the solution on the water bath for three minutes with occasional mixing. Allow the mixture to cool, add 20 ml of water and mix well by stirring. Add 10 ml of ammonium hydroxide, dropwise, with constant stirring. Transfer the solution to a 50-ml graduated centrifuge tube, washing the casserole three times with 4 to 5-ml portions of water. Dilute to the mark with water, mix thoroughly and centrifuge.

Read the absorbency of each solution, including the blank, using an 18-mm cell at a wavelength of 0.420 microns. If the absorbency of the solution is higher than 0.6, select a suitable aliquot, dilute it (1:10, 1:20, or 1:50 volumes) and the blank to the same volume and read the absorbency of the sample aliquot and the blank.

Each sample determination must be processed and diluted in a manner similar to that used in preparing the corresponding concentration range of the standard curves. In each case the blank reading is subtracted from the sample reading. If a spectrophotometer other than a Coleman model is used, the dilutions used for obtaining the calibration curves in the ranges given may have to be varied.

REPORTING CONCENTRATIONS OF OXIDES OF NITROGEN, AS NITROGEN DIOXIDE, IN PARTS PER MILLION (DRY BASIS)

$$ppm = \frac{\frac{22.4}{W \times 46} \times \frac{100}{(100-M)} \times 10^3}{V_m \times \frac{P_c}{760} \times \frac{492}{T}} = \frac{7.53 \times W \times T \times 10^4}{V_m \times P_c \ (100-M)}$$

Where

W = weight of nitrogen dioxide, milligrams

P_c = pressure in sample flask, millimeters of mercury

T = room temperature, degrees Rankine (at the time of the P_c measurement)

V_m = measured net volume of flask, liters

M = moisture in gas sample at room temperature due to vapor pressure of solution in sample bulb, per cent by volume

To convert the ppm of NO_2 to stack conditions, multiply by a correction factor based on the water vapor content of the flue gases as shown on page 23.

CALCULATIONS

GAS DENSITY CORRECTION FACTOR CALCULATION

The per cent by volume of each component on a dry basis (carbon dioxide, oxygen, carbon monoxide, and nitrogen) is divided by 100 and multiplied by the quantity (1.000 - mol fraction of water) to give the mol fraction of each component on a wet basis. The mol fraction of each component on a wet basis (including water) is multiplied by its molecular weight, and the sum of these is the apparent molecular weight of the gas sample.

The specific gravity compared to air is the ratio of the molecular weight of the sample to 28.95, the average apparent molecular weight of air. The correction factor to be applied to gas velocities is calculated according to the following relationship:

$$G = \sqrt{\frac{1.00}{\text{specific gravity compared to air}}}$$

Where

G = gas specific gravity correction factor

TOTAL STACK GAS FLOW RATE AT STANDARD CONDITIONS

Generally it is convenient to compute the stack gas velocity assuming that the stack gases have the same specific gravity as air.

To calculate the flow rate when this procedure has been used the following formula is employed:

$$Q = V_R \times F \times G \times A \times \frac{520}{T} \times \frac{P}{29.9} \times 60$$

Where

- Q = flow rate, standard cubic feet per minute
- V_R = average velocity at reference point during test, uncorrected for specific gravity, feet per second
- F = flue factor
- G = specific gravity correction factor
- A = area of stack cross section, square feet
- T = temperature of stack gas, degrees Rankine (^{o}F + 460)
- P = pressure of stack gas, inches of mercury

MASS RATE OF EMISSION OF OXIDES OF NITROGEN (AS NO_2)

Since the evacuated flask is saturated with water vapor, all moisture in the sample subsequently introduced into the flask will condense out. Thus the net flask volume is the dry sample volume, and the analytical results will be on a dry gas basis.

To convert oxides of nitrogen from the dry basis to stack conditions, the following calculation is used:

$$\text{ppm stack conditions} = \text{ppm dry basis} \left(1 - \frac{\% \text{ moisture}}{100}\right)$$

To convert parts per million (stack conditions) to grains per standard cubic foot (standard conditions being defined as 60°F, 1 atmosphere):

$$\text{Gr/SCF} = \text{ppm} \times \frac{\text{mol wt } NO_2}{379 \times 10^6} \times 7000 = 0.000849 \times \text{ppm}$$

To convert NO_2 concentration to 12% CO_2 basis:

$$\text{ppm } NO_2 \text{ @ 12\% } CO_2 = \frac{12 \times \text{ppm } NO_2 \text{ @ stack conditions}}{\%\ CO_2 \text{ @ stack conditions}}$$

To convert NO_2 concentration to 3% O_2 basis:

$$\text{ppm } NO_2 \text{ @ 3\% } O_2 = \frac{18 \times \text{ppm } NO_2 \text{ @ stack conditions}}{(21 - \%\ O_2 \text{ @ stack conditions})}$$

To convert NO_2 concentration to lbs./hr. basis:

$$\text{lbs/hr } NO_2 = \frac{\text{Gr/SCF} \times Q \times 60}{7000}$$

FORMS

The forms shown in the Appendix will be used for recording field data, analytical results, and calculations.

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LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT
LOS ANGELES
BASIN
XXXXXXXXXXXXXXXXXXXXXXXX
See the following Pages
for greater detail
XXXXXXXXXXXXXXXXXXXXXXXX
Steam Power Plants
Petroleum Refineries

LOS ANGELES
LONG BEACH
SCALE OF MILES
0 1 2 3 4 5

LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT

LOS ANGELES BASIN

SYMBOLS:

● Steam Power Plants

○ Petroleum Refineries

VI. APPENDIX

AIR POLLUTION CONTROL DISTRICT - COUNTY OF LOS ANGELES

Date_____

OXIDES OF NITROGEN SURVEY
TEST SUMMARY

Name of Firm_____

Location of Plant_____

Basic Equipment_____

Control Equipment_____

Equipment Tested_____

Length of Process Cycle _____ Time Cycle: Begin_____ End____

Sampling Station_____

Time of Test - Begin_____

- End _____

Gas Flow Rate, SCFM_____

Gas Temperature, °F_____

Av. Gas Velocity, FPS_____

NO_x, PPM by Volume, Stack Conditions_____

PPM by Volume, at 12% CO_2_____

PPM by Volume, at 3% O_2_____

Grains/SCF_____

Pounds/Hour_____

Pounds/Million BTU Gross Heating Value_____

% Moisture in Gases_____

CO_2, % (Stack Conditions)_____

O_2, % " " _____

CO, % " " _____

N_2, % " " _____

% Excess Air_____

Operating Conditions_____

AIR POLLUTION CONTROL DISTRICT - COUNTY OF LOS ANGELES

COMPANY _____ PAGE _____

_____ DATE _____

GRAB SAMPLE RESULTS, OXIDES OF NITROGEN AS NO_2

Load Condition _____

Sample Station	Time	PPM				Grains/SCF Stack Conditions	Lbs/hr Loss	Lbs/Million BTU Gross Heating Value
		Dry Basis	Stack Conditions	12% CO_2	3% O_2			

AIR POLLUTION CONTROL DISTRICT - COUNTY OF LOS ANGELES

TEST NO._____ PAGE_____

SAMPLING STATION_____ DATE_____

MOISTURE AND GAS DENSITY CALCULATIONS

PER CENT WATER VAPOR IN GASES

Time	Dry Bulb °F	Wet Bulb °F	Dew Point °F	Vapor Pressure In. Hg	Water Vapor %

GAS DENSITY CORRECTION FACTOR

Component Volume Per Cent/100 x Moisture Correction x Mol. Wt. = Weight per Mole Wet Basis

Water		1.0	18	
Carbon Dioxide	Dry Basis		44	
Carbon Monoxide	Dry Basis		28	
Oxygen	Dry Basis		32	
Nitrogen	Dry Basis		28	

Average Molecular Weight _____

A. Density of gas referred to air = $\frac{\text{Av. Mol. Wt.}}{28.95}$ = _____

B. Gas density correction factor = $\sqrt{\frac{1.00}{A}}$ = _____ _____

AIR POLLUTION CONTROL DISTRICT - COUNTY OF LOS ANGELES

TEST NO._____ PAGE _____

SAMPLING STATION_____ DATE _____

METER DATA AND CALCULATIONS

Time	Gas Meter			Impinger Temp. °F T_1				
	Reading Cu. Ft. V_m	Vac. In. Hg P_m	Temp. °F T_m					

Material collected_____ Water Condensate_____

Sampling Point_____ Sampling Nozzle Diameter_____

A. Condensate Volume, ml_____

B. Condensate Vapor Volume, $0.00267 \times C \times (460 + T_m)/(29.9 - P_m)$, Cu. Ft.___

C. Total Meter Volume, V_m + B Cu. Ft._____

AIR POLLUTION CONTROL DISTRICT -- COUNTY OF LOS ANGELES

TEST NO. _____ PAGE _____

SAMPLING STATION _____ DATE _____

MOISTURE AND GAS DENSITY CALCULATIONS

PERCENT WATER VAPOR IN GASES

A. GAS PRESSURE AT METER, IN. Hg (ABSOLUTE) _____

B. VAPOR PRESSURE OF WATER AT IMPINGER TEMP., IN. Hg _____

C. VOLUME OF METERED GAS, CU.FT. _____

D. VOLUME OF WATER VAPOR METERED, B×C/A, CU.FT. _____

E. VOLUME OF WATER VAPOR CONDENSED, CU.FT. _____

F. TOTAL VOLUME OF WATER VAPOR IN GAS SAMPLE, D+E, CU.FT. _____

G. TOTAL VOLUME OF GAS SAMPLE, C+E, CU.FT. _____

H. PERCENT WATER VAPOR IN SAMPLED GAS, 100×F/G _____

GAS DENSITY CORRECTION FACTOR

COMPONENT	VOLUME PERCENT/100	× MOISTURE CORRECTION	× MOL. WT.	= WEIGHT PER MOLE WET BASIS
WATER		1.0	18	
CARBON DIOXIDE	DRY BASIS		44	
CARBON MONOXIDE	DRY BASIS		28	
OXYGEN	DRY BASIS		32	
NITROGEN	DRY BASIS		28	

AVERAGE MOLECULAR WEIGHT [ ]

J. DENSITY OF GAS REFERRED TO AIR = $\frac{\text{AV. MOL. WT.}}{28.95}$ = _____

K. GAS DENSITY CORRECTION FACTOR = $\sqrt{\frac{1.00}{J}}$ = _____

16-55D10

AIR POLLUTION CONTROL DISTRICT -- COUNTY OF LOS ANGELES

TEST NO. _____ PAGE _____

SAMPLING STATION _____ DATE _____

GAS VELOCITY DATA

POINT	VEL. HEAD IN. H_2O	TEMP. ^oF	VELOCITY FT/SEC	VEL. HEAD IN. H_2O	TEMP. ^oF	VELOCITY FT/SEC	VEL. HEAD IN. H_2O	TEMP. ^oF	VELOCITY FT/SEC

A. AVERAGE VELOCITY (TRAVERSE) FT/SEC _____

B. AVERAGE VELOCITY (REFERENCE PT.) FT/SEC _____

C. FLUE FACTOR A/B _____

D. PITOT CORRECTION FACTOR _____

E. GAS DENSITY CORRECTION FACTOR _____

F. CORRECTED VELOCITY, A×D×E, FT/SEC _____

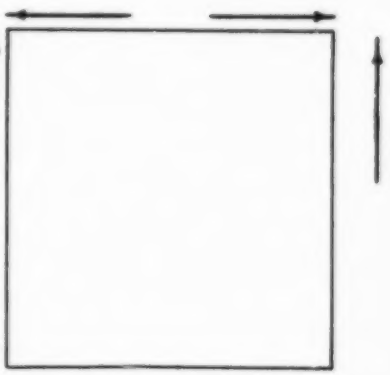
OR B×C×D×E, FT/SEC _____

G. AREA OF FLUE, SQ. FT. _____

H. AVERAGE FLUE TEMPERATURE, ^oF _____

J. FLOW RATE, F×G×60, CFM _____

K. FLOW RATE, 520×J/(H+460), SCFM _____



16-55D12

AIR POLLUTION CONTROL DISTRICT -- COUNTY OF LOS ANGELES

TEST NO. _____ PAGE _____

SAMPLING STATION _____ DATE _____

GAS VELOCITY DATA

POINT	VEL. HEAD IN. H_2O	TEMP. ^oF	VELOCITY FT/SEC	VEL. HEAD IN. H_2O	TEMP. ^oF	VELOCITY FT/SEC	VEL. HEAD IN. H_2O	TEMP. ^oF	VELOCITY FT/SEC

A. AVERAGE VELOCITY (TRAVERSE) FT/SEC _____

B. AVERAGE VELOCITY (REFERENCE PT.) FT/SEC _____

C. FLUE FACTOR A/B _____

D. PITOT CORRECTION FACTOR _____

E. GAS DENSITY CORRECTION FACTOR _____

F. CORRECTED VELOCITY, A×D×E, FT/SEC _____

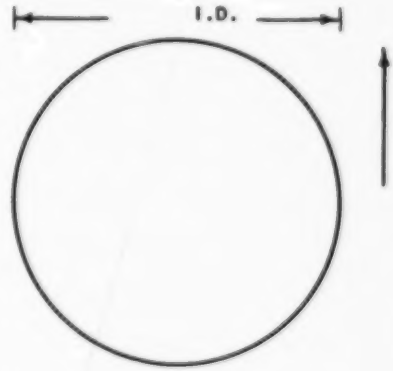
OR B×C×D×E, FT/SEC _____

G. AREA OF FLUE, SQ. FT. _____

H. AVERAGE FLUE TEMPERATURE, ^oF _____

J. FLOW RATE, F×G×60, CFM _____

K. FLOW RATE, 520×J/(H+460), SCFM _____



16-55013

EQUIPMENT DATA SHEET FOR NO_x PROJECT

Company Name _____

Address _____ Telephone No. _____

Person Contacted _____ Title _____

Date of Test _____ Duration: From_____To_____

Equipment Design Data

1. Type of equipment
2. Manufacturer
3. Description
   a. Size (physical dimensions of firebox and stack)
   b. Rating
   c. Flow path of combustibles and products through equipment
   d. Burners - Oil
      (1) Manufacturer _____ Model _____
      (2) Location and spacing
      (3) Capacity per burner
      (4) Method of atomization _____ Diff.Press._____
   e. Burners - Gas
      (1) Manufacturer _____ Model _____
      (2) Location and spacing
      (3) Capacity per burner
   f. Burners - Combination
      (1) Manufacturer _____ Model _____
      (2) Location and spacing
      (3) Rated capacity for combination firing

Equipment design Data (cont.)

3. g. Combustion Air

(1) Type of draft

(2) Amount of preheat

(3) Location of entry point in relation to burner

(a) Primary air

(b) Secondary air

(4) Method of combustion control

(a) Automatic _____

(b) Semi-automatic _____

(c) Manual _____

(5) Recommended range of excess air _____

h. Fuel

(1) Oil

(a) Type

(b) Composition

(c) Viscosity

(d) Preheat temperature

(e) Heat content

(f) API gravity

(2) Gas

(a) Composition

(b) Heat content

(3) Other fuel

(a) Composition

(b) Heat content

Equipment Operating Test Data

1. Fuel
   a. Rate of flow
      (1) Oil_____lbs. per hour
      (2) Gas_____cu. ft./hour
      (3) Other
      (4) % of rated capacity: Oil_____Gas_____
   b. Preheat temperature_____(oil)
   c. Location of burners in service _____
2. Combustion Air
   a. Preheat temperature
   b. Number and location of air registers in operation_____
   c. Turbulence
      (1) Register swirl
         (a) Clockwise (looking at front of boiler)
         (b) Counterclockwise
      (2) Pressure differential across register
   d. Per cent excess air in combustion process
3. Flame conditions
   a. Estimated length X diameter
   b. Brightness and color
   c. Other physical characteristics
   d. Temperature
4. Flue Gas
   a. Point of sampling (flowwise)

Equipment Operating Test Data (cont.)

4. b. Temperature

    (1) At sampling point

    (2) At point of discharge

    (3) At other points

  c. Per cent of recirculation

5. Associated equipment operation

  a. Electrical load on generator

  b. Steam temperature from boiler

    (1) Main

    (2) Reheat

  c. Steam pressure from boiler

    (1) Main

    (2) Reheat

6. Brief historical summary of recent furnace operation:

  Dates of last cleaning, etc.

7. Visible stack emissions

8. Process description

Data taken by_____

COMPRESSOR DATA SHEET

Company Name _____

Location _____ Telephone No._____

Person Contacted _____ Title _____

Date of Test _____ Time of Test _____

Equipment Design Data

Type _____ Manufacturer _____

Number of Cycles _____ Number of Compressors _____

Rated Capacity, Horsepower _____

Compressor No. _____ Engine No. _____

Engine RPM's _____

Equipment Operating Test Data

Type of Service _____

Normal Load, % of Rated Capacity _____

Operating Factor (% of time in operation) _____

Average Fuel Consumption, MCFD _____

INTAKE MANIFOLD PRESSURE, in. Hg. _____

Engine RPM's _____

Test Data

NO_x, ppm by volume in exhaust
Orsat analysis of exhaust
Wet bulb and dry bulb temperatures
Actual analysis of fuel gas used

Note: Most fuel gas burning rates will have to be calculated from rated brake horsepower and Btu/brake horsepower hour (100% loading) and corrected for load factor.

Exhaust volumes will have to be calculated by use of a carbon balance.